Beta-Decay Branching Ratio of ^{21}Na

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Our recent measurement of the β-ν correlation coefficient in the beta decay of laser trapped ^{21}Na, $a_{\beta\nu}$ = 0.5243 ± 0.0092, differs by 3.6σ from the Standard Model prediction of $a_{\beta\nu}$ = 0.558 ± 0.003 [1,2]. The uncertainty in the branching ratio to the excited state of ^{21}Ne (see Fig. 1) is the largest systematic uncertainty in the measurement.

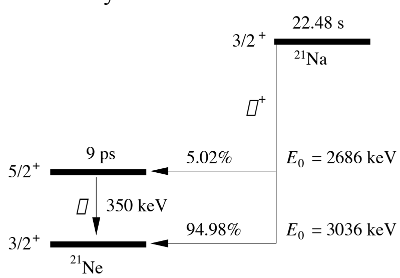

FIG. 1: ^{21}Na decay scheme.

The accepted value of the branching ratio is 5.02% ± 0.13%. This is in agreement with shell model estimates of 5 ± 1%, but there are large disagreements among previous measurements (see Fig. 2) [3-7]. The resulting systematic uncertainty in the ^{21}Na experiment is 0.7% in $a_{\beta\nu}$. Reducing the uncertainty in the branching ratio by a factor of 3 to a relative uncertainty of 1% will allow us to determine the β-ν correlation as well as any other β decay correlation more accurately.

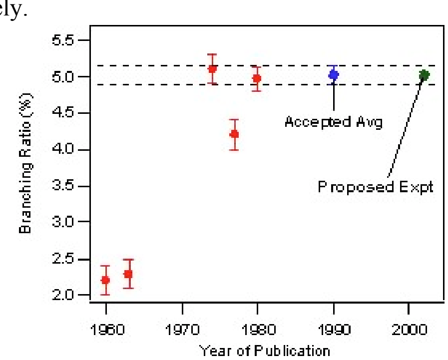

FIG. 2: Previous measurements of ^{21}Na decay branching ratio to the excited state of ^{21}Ne.

Previous measurements compared the ratio of 350 keV to 511 keV annihilation γ-rays, and suffered from presence of β+ decay contaminants. We are working on a different approach, taking advantage of recent developments in radioactive beams. During 2003, we had a preliminary run at the ISAC facility at TRIUMF which can deliver a pure ^{21}Na beam with <0.1% contaminants at 1 MeV/amu. The technique counts individual accelerated ^{21}Na ions stopped in a thin scintillator and compares the particle number to the number of 350 keV γ-rays detected by a calibrated high purity Ge detector. The beam count was 10^5 - 10^6 ions/s to prevent pileup. A total of 10^9 particles on target are required to reach the proposed sensitivity.

During the 2003 run, a plastic scintillator (BC-422) of 100 μm thickness was used. The rate of degradation of this scintillator due to radiation damage was unacceptably high. For the next run, we will use YAP:Ce crystal scintillator which has been measured to have a higher radiation damage threshold by a factor of roughly 100 for gamma rays [8]. A recent test at the LBNL 88-inch Cyclotron using stable Na beam at similar energies indicate that YAP:Ce is ~30 times more durable to radiation damage than the plastic scintillator, and the damage will be limited for the dose required by this experiment (see Fig. 3).

We are collaborating with Peggy McMahan to develop the use of YAP:Ce for diagnostics of the heavy-ion "cocktail beams" at the cyclotron. Currently plastic scintillators are used to measure the beam current and radiation damage requires the scintillators to be replaced every week. Tests with 180 MeV Ar^{16+} and $Kr^{27\text{-}29+}$ ions show clear pulse height spectra with little sign of damage. The technique appears promising and more tests are underway.

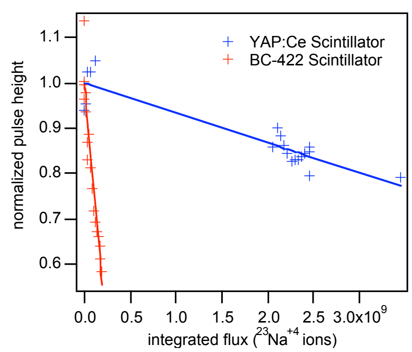

FIG. 3: Pulse height vs. number of incident ^{23}Na on YAP:Ce and BC-422.

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